Listing of Claims

What is claimed is:

1. (Original) A method for controlling a data flow in a data network, the method comprising:

    setting a stable integral controller gain k_i for said data network;

    specifying a plurality of precedence grades, each of said precedence grades having a priority associated thereto;

    for each precedence grade, calculating a cumulative data arrival rate R(n) where R(n) is the sum of the data arrival rates for a particular precedence grade under consideration plus the data arrival rates of all precedence grades with a higher priority than said particular precedence grade under consideration;

    for each precedence grade calculating a normalized error signal e(n), according to the relation

    $e(n) = (T(n) - R(n))/x$,

    where T(n) is an assigned precedence grade capacity at time n, and x is a nominal packet size;

    for each precedence grade computing a mark/drop probability p(n) according to the relation

    $$p(n) = \min \{ \max [p(n-1) + k_i \cdot \Delta t \cdot e(n), 0] , p_{max} \}$$

    where Δt is the time interval between a $(n-1)^{th}$ and the n^{th} computation, and $0 < p_{max} \leq 1$; and

    for each precedence grade executing a packet mark/drop routine based upon the calculated mark/drop probability p(n).

2. (Original) The method of claim 1 wherein the number of precedence grades is three.

3. (Currently Amended) The method of claim 1 wherein the step of setting the~~a~~ stable integral controller gain k_i for said data network is preceded by the step of pre-calculating a range within which all gains k_i result in a stable gain.

4. (Currently Amended) The method of claim 3 wherein the step of pre-calculating the~~a~~ range within which all gains k_i result in the~~a~~ stable gain for said data network is determined according to the method of:

   obtaining for said network a value for said network a set of parameters k, d_0, and τ,

   where k is a steady-state gain of said network,

   d_0 is a time delay of said network, and

   τ is a time constant of said network;

   determining a z_1 in the interval $\left(0, \frac{\pi}{2}\right)$ satisfying

$$\cot(z_1) = \frac{\tau}{d_0} z_1$$; and

   computing a range of stable gains k_i for said data network according to

$$-\frac{\tau}{kd_0^2} z_1 \sqrt{z_1^2 + \frac{d_0^2}{\tau^2}} < k_i < 0$$.

5. (Currently Amended) The method of claim 1 wherein the step of for each precedence grade measuring the~~a~~ data arrival rate R(n) at time n further comprises:

   filtering the data arrival rate R(n) according to the relation:

   $R'(n) = (1 - \beta)\cdot R'(n-1) + \beta\cdot R(n)$

   where β is a filter gain parameter such that $0 < \beta < 1$,

   R'(n-1) is the filtered data arrival rate at time n-1,

   R'(n) is the desired filtered data arrival rate at time n, and

R(n) is the cumulative data arrival rate at time n.

6. (Currently Amended) The method of claim 1 further comprising a step, preceding the step of for each precedence grade executing the~~a~~ packet mark/drop routine, of:
   for each precedence grade testing the cumulative data arrival rate R(n) against a rate threshold T_L specific to that precedence grade; and
   if the cumulative data arrival rate R(n) is below or equal to said rate threshold T_L then bypassing the step of executing a packet mark/drop routine for that precedence grade.

7. (Currently Amended) The method of claim 1 further comprising a step, preceding the step of for each precedence grade executing the~~a~~ packet mark/drop routine, of:
   for each precedence grade testing the cumulative data arrival rate R(n) against a rate threshold T_L common to all precedence grades; and
   if the cumulative data arrival rate R(n) is below or equal to said rate threshold T_L then bypassing the step of executing a packet mark/drop routine for that precedence grade.

8. (Currently Amended) The method of claim 1 wherein the step of executing the~~a~~ packet mark/drop routine further comprises marking/dropping packets according to a random number generator mark/drop scheme.

9. (Original) An apparatus for controlling a data flow in a data network, the apparatus comprising:
   an integral controller having an integral controller gain k_i setting for which the said network is stable;
   a cumulative data rate calculator for calculating a cumulative data arrival rate R(n) associated with each of said plurality of precedence grades, wherein R(n) is the sum of the data arrival rates for a particular precedence grade

under consideration plus the data arrival rates of all precedence grades with a higher priority than said particular precedence grade under consideration;

an error signal calculator for calculating a normalized error signal e(n) for each of said plurality of precedence grades according to the relation

$$e(n) = (T(n) - R(n))/x,$$

where T(n) is an assigned precedence grade capacity at time n, and x is a nominal packet size;

a mark/drop probability processor for computing a mark/drop probability p(n) for each of said plurality of precedence grades according to the relation

$$p(n) = \min \{ \max [p(n-1) + k_i \cdot \Delta t \cdot e(n), 0] , p_{max} \}$$

where Δt is the time interval between a $(n-1)^{th}$ and the n^{th} computation, and $0 < p_{max} \leq 1$; and

a packet mark/drop module for executing a packet mark/drop routine based upon the calculated mark/drop probability p(n).

10.(Original) The apparatus of claim 9 wherein the number of precedence grades is three.

11.(Original) The apparatus of claim 9 wherein the integral controller gain k_i setting for which the said network is stable is chosen from a pre-calculated range within which all gains k_i are gains for which said network is stable.

12.(Original) The apparatus of claim 11 wherein the pre-calculated range within which all gains k_i are gains for which said network is stable is determined according to the method of:

obtaining for said network a value for said network of a set of parameters k, d_0, and τ,

where k is a steady-state gain of said network,

d_0 is a time delay of said network, and

τ is a time constant of said network;

determining a z_l in the interval $\left(0, \frac{\pi}{2}\right)$ satisfying

$$\cot(z_1) = \frac{\tau}{d_0} z_1 \qquad ; \text{ and}$$

computing a range of stable gains k_i for said data network according to

$$-\frac{\tau}{kd_0^2} z_1 \sqrt{z_1^2 + \frac{d_0^2}{\tau^2}} < k_i < 0 \quad .$$

13.(Currently Amended) The apparatus of claim 9 wherein the cumulative data rate calculator ~~data arrival rate measurer~~ for measuring data arrival rate R(n) at time n further comprises:

a filter for filtering the data arrival rate R(n) according to the relation:

$$R'(n) = (1 - \beta) \cdot R'(n-1) + \beta \cdot R(n)$$

where β is a filter gain parameter such that $0 < \beta < 1$,

R'(n-1) is the filtered data arrival rate at time n-1,

R'(n) is the desired filtered data arrival rate at time n, and

R(n) is the cumulative data arrival rate at time n.

14.(Original) The apparatus of claim 9 further comprising:

a test module for testing the cumulative data arrival rate R(n) against a rate threshold T_L specific to that precedence grade; configured such that

if the cumulative data arrival rate R(n) is below or equal to said rate threshold T_L then bypassing the packet mark/drop module for that precedence grade.

15.(Original) The apparatus of claim 9 further comprising:

a test module for testing the cumulative data arrival rate R(n) against a rate threshold T_L common to all precedence grades; configured such that

if the cumulative data arrival rate R(n) is below or equal to said rate threshold T_L

then bypassing the packet mark/drop module for that precedence grade.

16.(Original) The apparatus of claim 9 wherein the packet mark/drop module further comprises a random number generator drop scheme module.

17. (Currently Amended) ~~An article of manufacture~~ A computer program product comprising a computer readable medium having stored thereon computer executable instructions for controlling a data flow in a data network, the computer executable instructions ~~article of manufacture~~ comprising:

~~at least one processor readable carrier and instructions carried on the at least one carrier; wherein the instructions are configured to be readable from the at least one carrier by at least one processor and thereby cause the at least one processor to operate so as to:~~

instructions for setting ~~set~~ a stable gain of a integral controller gain k_i for said data network;

instructions for specifying ~~specify~~ a plurality of precedence grades, each of said precedence grades having a priority associated thereto;

instructions for calculating, for each precedence grade, ~~calculate~~ a cumulative data arrival rate R(n) where R(n) is the sum of the data arrival rates for a particular precedence grade under consideration and the data arrival rates of all precedence grades with a higher priority than said particular precedence grade under consideration;

instructions for calculating, for each precedence grade, ~~calculate~~ a normalized error signal e(n), according to the relation

$$e(n) = (T(n) - R(n))/x,$$

where T(n) is an assigned precedence grade capacity at time n, and x is a nominal packet size;

instructions for computing, for each precedence grade, ~~compute~~ a mark/drop probability p(n) according to the relation

$$p(n) = \min \{ \max [p(n-1) + k_i \cdot \Delta t \cdot e(n), 0] , p_{max} \}$$

where Δt is the time interval between a $(n-1)^{th}$ and the n^{th} computation, and $0 < p_{max} \leq 1$; and

instructions for executing, for each precedence grade, ~~execute~~ a packet mark/drop routine based upon the calculated mark/drop probability $p(n)$.

18. (Cancelled)